DACA42- 02-C-0001

LOGANEnergy

Residence of Army Lt. Col. Luster PEM Demonstration Program, Fort McPherson, Atlanta, Georgia Final Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Fort McPherson
Atlanta, Georgia

March 15, 2005

Executive Summary

In May 2003 LOGANEnergy Corporation received a modification to its CERL BAA FY01 PEM Demonstration Contract that added Ft McPherson, GA to its project sites. LOGAN completed the installation of one 5kW Plug Power GenSys5C PEM fuel cell at Ft. McPherson, and started the unit on October 31, 2003. However, because of delays in acquiring high-speed commercial Ethernet service, the Web SCADA system was not activated until late February 2004. The project concluded its one year of performance testing and evaluation on November 31, 2004 achieving 90% availability. Site deconstruction concluded in late December 2004.

The Combined Heat and Power (CHP) installation operated electrically in a grid parallel/grid independent configuration that connected several kitchen appliances and convenience outlets onto the fuel cell's critical load panel. However, the base did not experience any grid failures during the project period of performance, so the emergency panel did not have a real test experience.

The facility's water heater captured the unit's waste heat output. Project instrumentation included an external wattmeter, BTU meter, and a gas flow meter. A phone line was connected to the power plant communication's modem in order to receive or initiate call-outs to provide quick response to system alarms or events requiring service and attention. In addition, LOGAN installed a Web-enabled SCADA system that captured real time data used for operational control, data collection, resource management and alarming.

The Point of Contact for this project was Luke Wayland. He may be reached at (404) 464-4177. The total energy cost savings achieved during the project was $211.31.

Table of Contents

Update Table of Contents

Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Residence of Lt. Col. Luster PEM Demonstration Program, Fort McPherson, Atlanta, Georgia

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation

1080 Holcomb Bridge Road
BLDG 100- 175
Roswell, GA 30076
(770) 650- 6388

DUNS 01-562-6211
CAGE Code 09QC3
TIN 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually. Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is scott_wilshire@plugpower.com.

4.0 Principal Investigator(s)

Name	Samuel Logan, Jr.	Keith Spitznagel
Title	President	Vice President Market Engagement
Company	Logan Energy Corp.	Logan Energy Corp.
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5.0 Authorized Negotiator(s)

Name	Samuel Logan, Jr.	Keith Spitznagel
Title	President	Vice President Market Engagement
Company	Logan Energy Corp.	Logan Energy Corp.
Phone	770.650.6388 x 101	860.210.8050
Fax	770.650.7317	770.650.7317
Email	samlogan@loganenergy.com	kspitznagel@loganenergy.com

6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company
Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.
In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability. LOGAN performs the quarterly and annual service prescribed by the UTC, and performs other maintenance as required. The periods of unavailability are chiefly due to persistent inverter problems that seem to be endemic to the Toshiba power conditioning balance of the system. Field modifications and operating adjustments have largely cured the problem. Quarterly service events take 10 hours to complete with the unit under load, and the annual event takes approximately 35 hours with the unit shut down.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.

Plug Power
Mr. Scott Wilshire.
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1338

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work. The units are located at residential sites at Patuxant River Naval Air Station, MD and operate in standard gird connected/grid independent configurations. Both operate at 4.5kWe and have maintained 98% availability. The units, S/Ns 241 and 242 are two of the very latest GenSys models to reach the field. S/N 242 is Plug Power's first LPG fueled system to go into the field. Both have set new performance standards, and raised expectations for near term commercial viability for this product. Operations to date are indicative of the success of the various test and evaluation programs that have been conducted over the past two years.

c) Contract: A Partners LLC; Commercial PC25 Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.

Mr. Ron Allison
A Partners LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA. The system operating configurations allow for both grid parallel and grid independent energy service. The grid independent system is integrated with a Multi Unit Load Sharing (MULS) electronics package and static switch, which initial development was funded by ERDC CERL in 1999. This is the third fuel cell installation that uses the MULS System. The thermal recovery package installed in the project includes a 100-ton chiller that captures 210 degree F thermal energy supplied by the three fuel cells to support cooling loads on the first three floors of the host facility. The fuel cells also provide low-grade waste heat at 140 degrees F that furnishes thermal energy to 98 water source heat pumps located throughout the 12-story building during the winter months.

7.0 Host Facility Information

U. S. Army Garrison, Fort McPherson, is located in Atlanta, Georgia. Fort McPherson serves and supports a number of military departments: Active duty and reserve component soldiers, sailors, airmen and Marines, Department of Defense civilians, military retirees and family members of all of these.

In 1867 to 1868, a 10-company post was constructed on the 53 acres of leased ground at the southwest corner of Atlanta, and on December 30, 1867, was named McPherson Barracks in honor of Union Maj. Gen. James Birdseye McPherson. During the period 1881-1886, McPherson Barracks continued to serve as a summer encampment due to its climate, especially for troops assigned to subtropical Florida.

Today, as a headquarters, Fort McPherson houses and supports these major activities: U.S. Army Forces Command, Third U.S. Army/Forces Central Command, U.S. Army Reserve Command, Southeast Region Office for the U.S. Army, and the U.S. Army Center for Health Promotion and Preventative Medicine-South.

Georgia Power and Georgia Gas Company provide electricity and natural gas to the base, respectively.

8.0 Fuel Cell Installation

After reviewing several possible sites on the base, the home of Lt. Col and Mrs. Luster, Figure 1, was selected to host the installation. In June 2003, representatives of CERL, LOGAN, and Fort McPherson held the project kick-off meeting. In July 2003, Plug Power shipped the unit, S/N 199, to Fort McPherson, where it was placed on its pad, as seen in Figure 2. The site is the oldest building on the base, circa 1880. Additional photos document the several tasks involved in the installation of the project. LOGAN worked closely with the Fort McPherson Environmental Department to insure the installation satisfied all environmental requirements. No permits were required or issued for this site. The installation proceeded according to plan with minimal inconvenience to the base or the host site; requiring 154 man-hours to complete. The first start occurred on Oct 31, 2003. With the connection of the Ethernet service on February 2, 2004, real time data became available for the first time.

Figure 1, Fuel Cell Pad Site

Figure 2, Fuel Cell on Pad Site

Figure 3 shows another photo of the unit on its pad. The gray box in the background houses the DI/RO water supply panel as well as the RTU, which provides Web connectivity to the site.

Figure 3, Natural Gas & Electrical Interfaces

Figure 4, Meter and Housings

Figure 4 is a close up of the equipment housing mentioned above. The photo also shows the installation of both the fuel cell electric and natural gas meters.

Installation Line Diagram

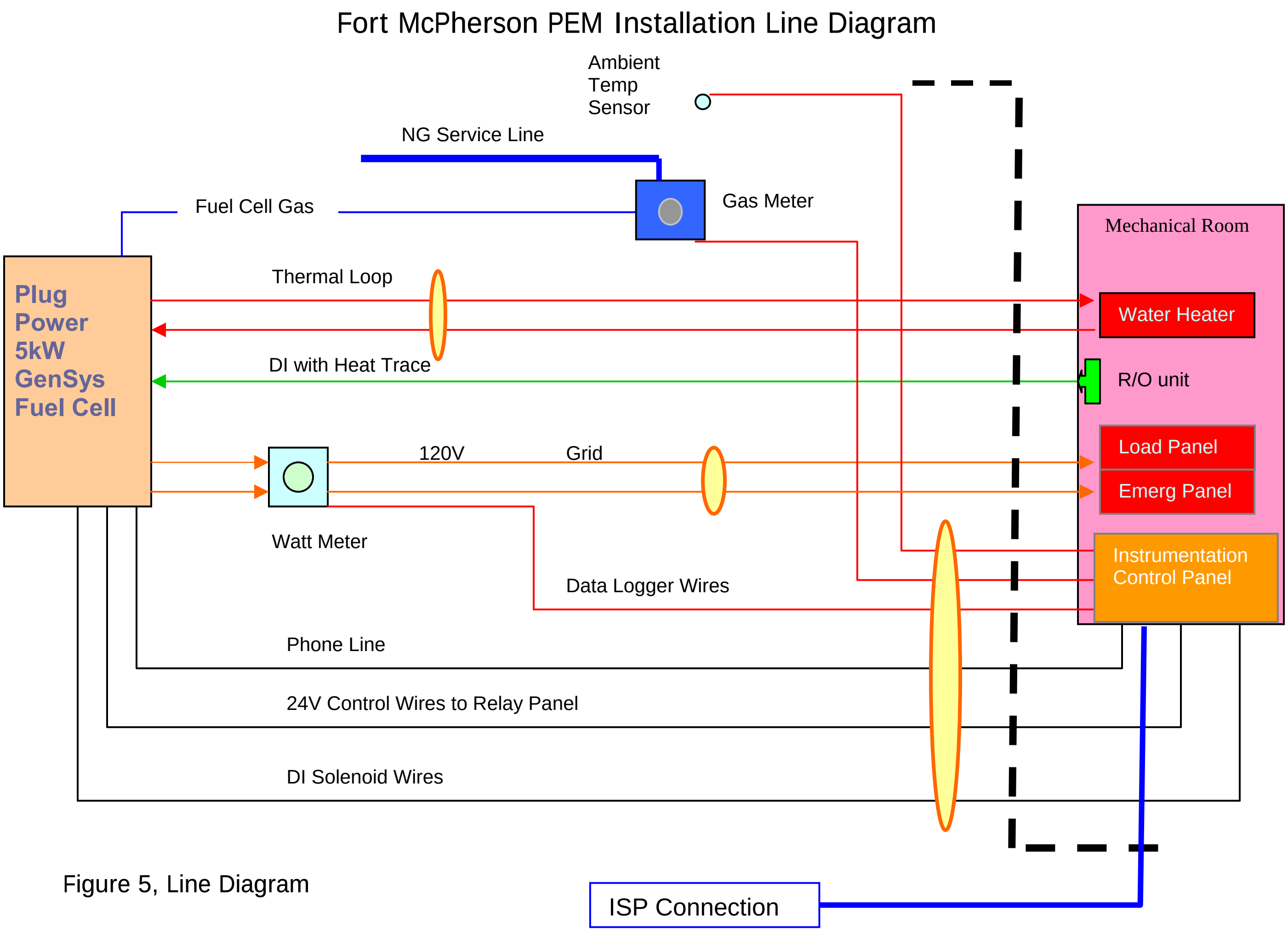


Figure 5, Line Diagram

Figure 5, above, describes a one line diagram of the Fort McPherson fuel cell installation. The diagram illustrates utility and control interfaces including, gas, power, water and instrumentation devices installed in both the residential equipment room and the exterior equipment chest at the Luster residence.

The electrical conduit between the facility load panels and the fuel cell are approximately 40 feet. The Reverse Osmosis/DI water tubing that carries filtered process water to the power plant is approximately 10 feet distance, and the thermal recovery piping between the fuel cell and the hot water heater is also approximately 40 feet.

9.0 Electrical System

The fuel cell inverter has a power output of 110/120 VAC at 60 Hz, matching the building distribution panel in the mechanical room with its connected loads at 110/120 VAC. The installation includes both a grid parallel and a grid independent configuration as indicated in Figure 6. The unit provides stand-by power to a new 100amp critical circuit panel that serves several kitchen appliances and other plug loads. A two-pole wattmeter monitors both the grid parallel and grid independent conductors to record fuel cell power distribution to both the existing panel and the new critical load panel.

10.0 Thermal Recovery System

Fuel Cell waste heat flows to a Heliodyne heat transfer coil that maintains the domestic hot water tank at 130 degrees F, which was adequate to meet the domestic hot water demand of the facility.

Figure 6, below, shows the method of providing fuel cell waste heat with the existing hot water tank. The “U” shaped coil is a Heliodyne Heat Exchanger mounted on the wall adjacent to the tank. The other major components are indicated in the boxes below with arrows pointing to their locations.

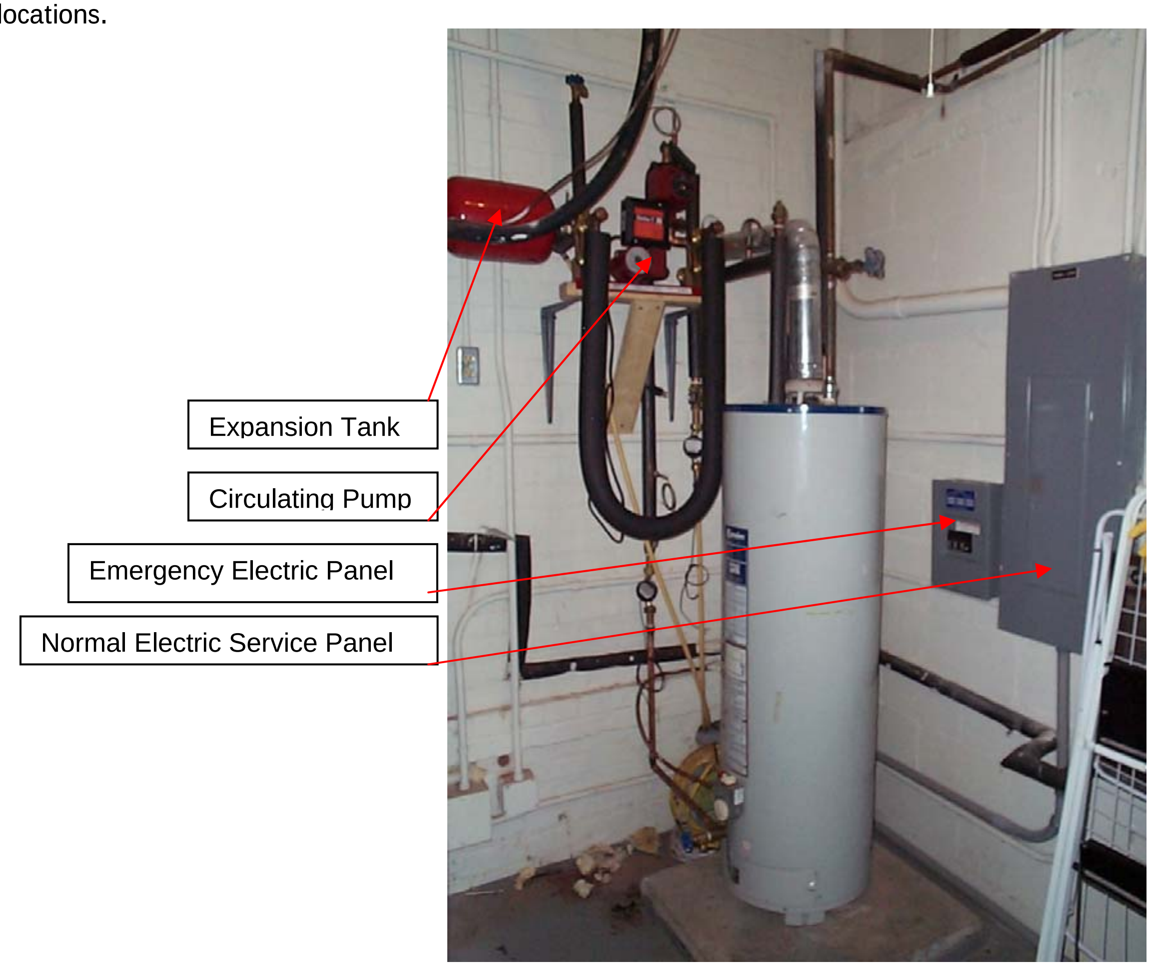


Figure 6, Electrical and Thermal Recovery Installation

11.0 Data Acquisition System

Figure 7, Instrumentation and RTU Housing

Figure 7 displays a photo of a LOGAN fuel cell technician connecting instrumentation wiring to the RTU terminals that will transmit operating and performance data via a VPN to LOGAN's distributed generation control center in Rochester, NY.

Over the course of developing the several sites in the FY01 PEM Program, LOGAN has encountered great difficulty in acquiring a dedicated phone line for the fuel cell at every site. In the best case this has delayed starting the Demonstration Period by three weeks. Most sites have proven far more difficult. These experiences have taught LOGAN to be very explicit with the host POC at the kick-off meetings concerning the necessity for providing a dedicated phone line, since much of the success of the project is dependent upon reliable communications with the unit.

As with its Coast Guard Station PEM installation in New Orleans, Louisiana, LOGAN decided once again to install a Web-based, real time, data management and reporting system at Ft McPherson. To do this LOGAN contracted with Connected Energy Corporation, CEC, to provide the service. The drawing seen in Figure 8, below, describes the architecture of the CEC system operating at the site. The system provides a comprehensive data acquisition solution, and also incorporates remote control, alarming, remote notification, and reporting functions as well by means of a VPN that maintains connectivity between the fuel cell site and the control center in Rochester, NY.

With the introduction of this system at Ft McPherson, LOGAN continued to learn new lessons in Web based CHP resource management. The service installation at Ft McPherson was initially hampered by miscommunications between LOGAN and the POC as to what high-speed service was available to the base. Once LOGAN determined that high-speed Internet service could be provided to the site, the project waited on service to be processed for the site for nearly three months. Other problems ensued with billings. The service provider would only send bills to the address of the actual service not to LOGAN's office. So it was not until a service interruption that LOGAN discovered this issue and promptly paid for the entire year's service to prevent further interruptions.

Another important lesson that LOGAN has learned with this system is the critical role that individual instrumentation component parts play in supplying the data to the web interface. The CEC system requires very precise signals from the outputs of these devices. The gas meters, watt meters, flow meters and thermal elements invariably require signal strength adjustment at the RTU terminals to insure that their discrete inputs are readable by the CEC system.

Discovering the proper voltage range required for each signal loop is most often achieved by trial and error, requiring multiple site visits to establish a readable connection. In other instances LOGAN has discovered that flow metering devises and thermal couples often require high levels of maintenance and/or replacement to support continuous data collection. It was not until late April that these issues were clearly diagnosed and appropriate corrections made so that thermal recovery data could be accurately maintained. However, the field experience learning curve has been rapid, and LOGAN is building a body of knowledge and expertise with this system that will yield improved results and better data as new sites are added to the WEB support system in the future. Figure 9, on page 13, is an example of one of many data screens that are maintained by the CEC system and displayed on the web. A sample data graph is also attached to Appendix 2 providing heat recovery data for the months of February through May.

To view the operation of this unit, online go to: https://www.enerview.com/EnerView/login.asp Then login as: logan.user and enter password: guest. Select the box labeled Ft McPherson. Then you may navigate the site or other LOGAN sites using the tool bars or html keys.

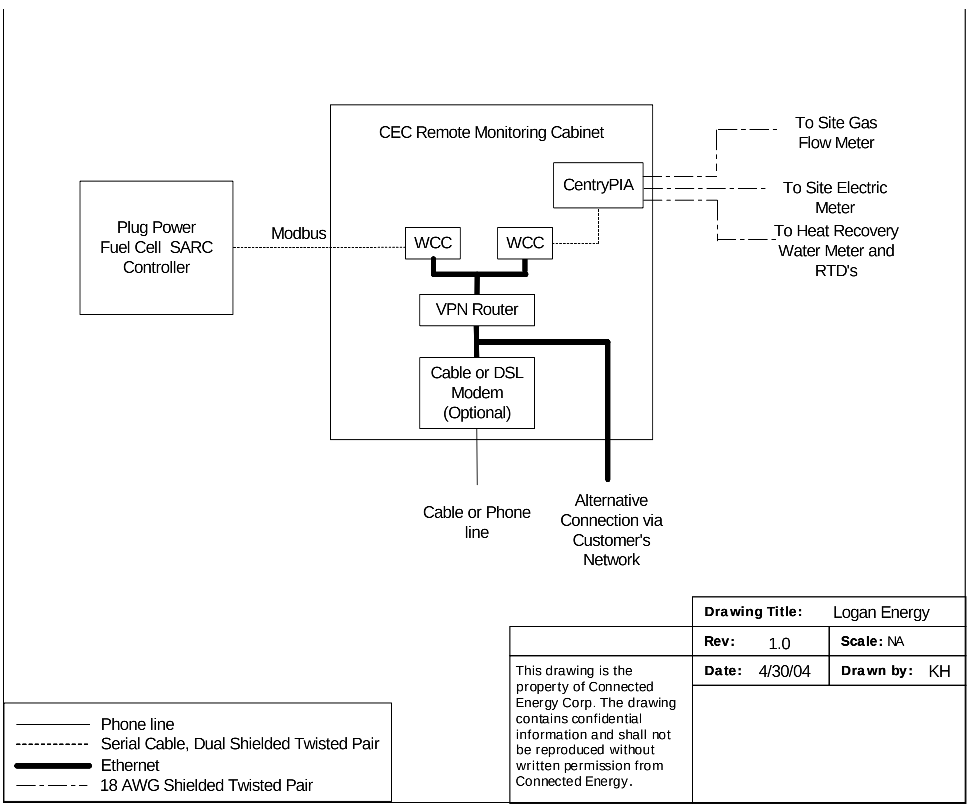


Figure 8, Connected Energy System Architecture

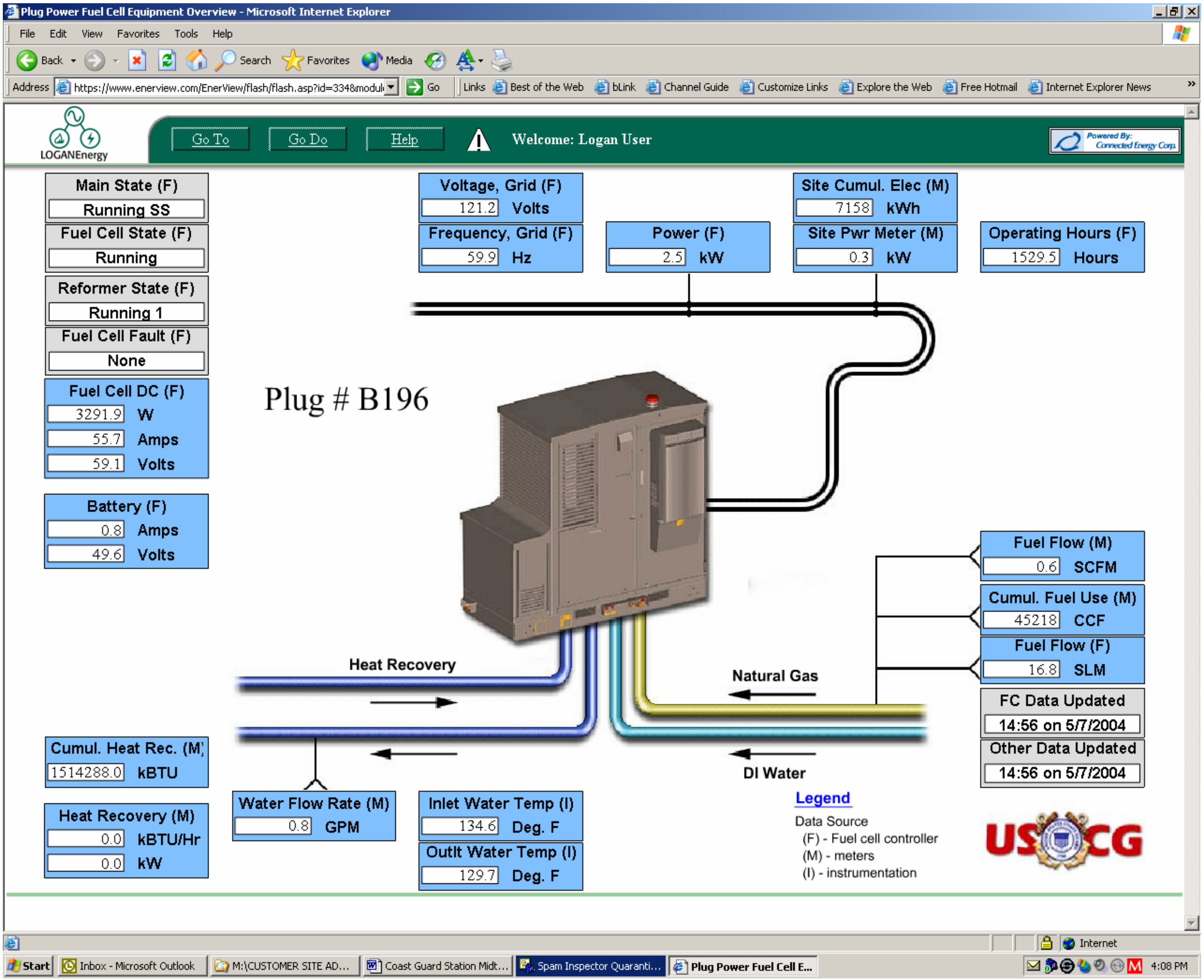


Figure 9, Connected Energy Web Data Screen

12.0 Fuel Supply System

LOGAN connected the fuel cell gas piping into the existing natural gas service line adjacent to the fuel cell pad, and installed a flow meter to calculate fuel cell usage as indicated in Figure 4. A regulator at the fuel cell gas inlet maintains the correct fuel cell operating pressure at 14 inches water column.

13.0 Program Costs

Fort McPherson PEM Demonstration Program

Project Utility Rates						
1) Water (per 1,000 gallons)			$ 1.31			
2) Utility (per KWH)			$ 0.065			
3) Natural Gas (per MCF)			$ 5.80			
First Cost				**Budgeted**	**Actual**	**Variance**
Plug Power 5 kW SU-1				$ 65,000	$ 65,000	**$ -**
Shipping				$ 1,800	$ 1,500	**$ (300)**
Installation electrical				$ 3,175	$ 2,182	**$ (993)**
Installation mechanical & thermal				$ 6,800	$ 6,500	**$ (300)**
Instrumentation, Data Package				$ 3,750	$ 8,750	**$ 5,000**
Site Prep, labor materials				$ 1,325	$ 1,024	**$ (301)**
Technical Supervision/Start-up				$ 2,047	$ -	**$ (2,047)**
Decommissioning Site Restoration/Hrs				$ 850	$ 1,120	$ 270
Total				**$ 84,747**	**$ 84,956**	**$ 209**
Annual Technical Services	**Budgeted**	**Actual**	**$/Hr**	**Budgeted**	**Actual**	**Variance**
Technical Services Maintenance/Hrs.	210	325	$ 80	$ 16,800	$ 26,000	$ 9,200
Report Writing/Hrs	40	40	$ 100	$ 4,000	$ 4,000	$ -
Perdiem costs/days	36	55	$ 98.00	$ 3,528	$ 5,390	$ 1,862
Travel Costs				$ 3,110	$ 1,100	$ (2,010)
Mgmt Performance Monitoring/Hrs.	130	130	$ 100	$ 13,000	$ 13,000	$ -
Total Services	**416**	**550**		**$ 40,438**	**$ 49,490**	**$ 9,052**
Total Project & G+A				**$ 147,718**	**$ 158,646**	**$ 10,928**
Annual Operating Expenses	**Budgeted**	**Actual**	**$/Hr**	**Budgeted**	**Actual**	**Variance**
Natural Gas Mcf/ hr @ 2.5kW	0.0328	0.0351	$ 0.190	$ 1,502	$ 1,604	$ 103
Water Gallons per Year	14,016				$ 18	$ 18
Natural Gas Cost/kWh			**$ 0.0762**			

Economic Summary	**Budgeted**	**Actual**	**Variance**
Forecast Annual kWH	19710	20743	1033
Annual Cost of Operating Power Plant kWH	$ 0.0771	$ 0.0733	$ (0.0038)
Credit Annual Thermal Recovery kWH	$ (0.0149)	$ (0.0184)	$ (0.0035)
Project Net Operating Cost kWH	$ 0.0622	$ 0.0549	$ (0.0073)
Displaced Utility cost kWH	$ 0.0651	$ 0.0651	$ -
Energy Savings (Increase)	$0.003	$0.010	$ 0.0073
Annual Energy Savings (Increase)	$56.28	$211.31	$ 155.03

14.0 Milestones/Improvements

As mentioned above in paragraph 9, the fuel cell inverter in GenSys5C S/N 196, used during this project, is the newly introduced MP-5. This improvement added a grid independent operating capability to the basic grid parallel configuration found on the previous versions of the GenSys5 SU-1 platform. This capability is an important milestone in the development of the Gensys5 product and for the PEM Program itself, as it is a significant developmental step on the pathway to product commercialization. In this particular project, that capability allowed LOGAN to install an "emergency Load" panel at the host site and transfer several circuits to that panel. In the event of a utility failure these circuits would have remained energized by the fuel cell. The circuitry and functionality describing this can be seen in Figures 5 and 6 above.

S/N 199 also took advantage of the capability to recover waste heat through the addition of a customer heat exchanger added to the unit for that purpose. Fuel cell heat was previously rejected through an air-cooled radiator on the unit, but the introduction of an extra heat exchanger allowed LOGAN to reject that heat to the host's hot water heater through a glycol loop. This process is more fully described in paragraph 10.0 above. With the help of a Heliodyne heat exchanger, the waste heat was more efficiently recovered for consumer applications. The Heliodyne is made up of a coil within a coil design, described in Figure 6, that provides double wall protection between the heat source and the heat sink in order to prevent contamination of potable water supplies. It was designed primarily for the solar heating industry, but proved to be very adaptable to this installation.

The Fort McPherson S/N 199 also took advantage of the application of new Web-based data acquisition technologies, with the help of Connected Energy Corporation. Because of problems obtaining a phone line in more remote/secure locations, LOGAN decided to experiment with a new Web based, real time data-management and reporting system. The drawing seen in Figure 8 describes the architecture of the CEC system operating at the site. The system provides a comprehensive data acquisition solution and also incorporates remote control, alarming, remote notification, and reporting functions. CEC's Central Operations Control Center in Rochester, New York, collects, stores, displays, alarms, archives site data, and maintains connectivity with the site. More explanations and descriptions of the hardware and its functionality can be found in paragraph 11.0 above.

15.0 Decommissioning/Removal/Site Restoration

Fuel Cell Decommissioning and site restoration occurred in late December 2004 and early January 2005 over a period of approximately 15 hours. All plumbing and heating systems and electrical circuits were restored to their original pre-test condition. The unit is still on the pad awaiting final removal. Thereafter, the pad will be removed and the lawn area reconstituted as necessary. This work was accomplished without any inconvenience to the occupants.

16.0 Additional Research/Analysis

In order to better assess the dependability and efficiency of the thermal recovery system, as well as many other features of the GenSys5C, LOGAN introduced Connected Energy's Web-based data acquisition technology. With the help of this system, fuel cells in LOGAN's service fleet can be monitored via the internet and Connected Energy can provide real time data for almost any statistic concerning GenSys5C operations.

The graphs in Appendix 1 show the fluctuation of several variables across S/N 199's period of operation. The first graph shown is of the fuel cell's AC Output Power from its initial start date. The work logs in Appendix 3 should be referenced for periods of inoperability.
The second graph in Appendix 1 is of Heat Recovery Loop Inlet/Outlet Temperatures from its initial recording date. The temperature difference between the inlet flows and outlet flows provides a better picture for how much and when heat is actually recovered at certain times of the day, month, or year. The delta between these temperatures can prove valuable in data analysis.

The third graph in Appendix 1 is of the fuel cell's Heat Recovery Rate from its initial recording date. Problems with the Connected Energy CHP sensors left a gap in the data for the first few months of S/N 196's operation; however technicians were able to correct the problem and began logging data in late February of 2004.
The fourth graph in Appendix 1 is of Heat Recovery Flow Rate from its initial recording date.
For each of these plots, the variable units are listed at the bottom of each graph.

Appendix section 4 labeled, Harmonics Testing, presents site data gathered from testing and verification of performance specifications of the GenSys AC inverter. The data describes three conditions; a. stand alone grid harmonics, b. the inverter harmonics in a grid connected configuration, and c. inverter harmonics in grid independent configuration. The IEEE Standard, 519-1992, that governs the performance of the Plug Power states that

1. Total Voltage Harmonic Distortion at rated inverter output is limited to 5% of fundamental frequency voltage, and
2. Individual Frequency Harmonics Distortion is limited to 3% of fundamental frequency voltage.

Referring to the Chart in Appendix 4, the test results indicate that at the time the measurements were taken, no individual Frequency Harmonic exceeded the IEEE standard of 3%, and that total Voltage Harmonic Distortion at 3.4% was well below the upper IEEE limit of 5%.

In Appendix section 5, LOGAN presents the results of the system thermal mapping conducted to measure the effectiveness of the fuel cell waste heat integration with the host water heater. The test determined the length of time to recover the tank from a cold start, the rate of transfer and the Btu's that were transferred. During the 2.5 hour test period, measurements were observed by reading the data over the fuel cell Web site as reported by Connected Energy. The charts on display in the Appendix describe these activities in great detail. While the fuel cell recovery rate takes up to 4 times as long as a standard gas or electric heater, this system did not cause any reported inconvenience to the occupants of the home, indicating that household demand and life styles will have a measured impact on the acceptability of fuel cell heat recovery even if the economics are positive. In this case, the thermal recovery option created a gas savings of $155 during the year test period.

17.0 Conclusions/Summary

After seven years of supporting many fuel cell installations at various locations throughout the US, the Ft. McPherson project was only LOGAN's third demonstration at a site located within an hour's drive of a field office. As a typical prior example, Barksdale AFB was a five-hour drive. Not only did this accessibility contribute to sustainable availability of the McPherson unit as compared to the earlier Barksdale project, it also enhanced technical training and improved the knowledge and skills of the attending engineer. As in the prior year Ft. Jackson, SC project, McPherson's proximity allowed the engineer to visit the site on many occasions just to test ideas, validate operating parameters as compared with other units operating in similar configurations, and gain new insight into system performance. As a result, this site contributed to the rapid expansion the company's fuel cell knowledge base and confidence, but similarly it has contributed valuable data to the PEM Program and to Plug Power engineering as well.

There were other firsts. The Ft McPherson project was the first to engage a host site listed on the National Historic Registry; requiring special attention to methods and means of conformal integration with the historic nature of the home. These plans were closely monitored and approved by Luke Wayland, site POC, who provided timely support and cooperation. The project also received the cooperative support of DOE Pacific Northwest Labs, who provided an engineer to work with LOGAN's staff, onsite, to perform a series of tests and measurements at the site.

In general terms, the Ft. McPherson project did not encounter any major obstacles or other events that patience and cooperation among the stakeholders did not eventually solve. However, gaining access to commercial ISP service in order to activate the Web SCADA system was a difficult and time consuming issue that has proved endemic to DOD installations. In this case a number of security issues and miscommunications caused a delay in data collection for the first two months of the project. Nevertheless, the lessons learned during the exercise have inured to the benefit of future sites. Another vexing issue proved to be the facility's use of propane-air peak shaving to support facility thermal loads during cold weather months. Since a natural gas fueled GenSys units cannot run on propane, these events proved to be very disruptive during the months of December 2003 and January 2004. The loss of availability during those periods had to be recovered in later months, and was successfully done so because of the high performance reliability achieved by S/N 199. The test period concluded with a total 7932 fuel cell load hours, and achieved overall availability of 90.5%.

Though the project budget approved by CERL amounted to $147,718, LOGAN provided an additional $10,928 in cost share to bring the project to a successful completion. The additional cost may be attributed to additional hours spent working through issues related to the Web/fuel cell interface, and learning how to properly wire the several system sensor outputs to the router terminals. Much of this was accomplished through trial and error with the testing/replacement of various components and small terminal resistors required to provide precise input voltages.

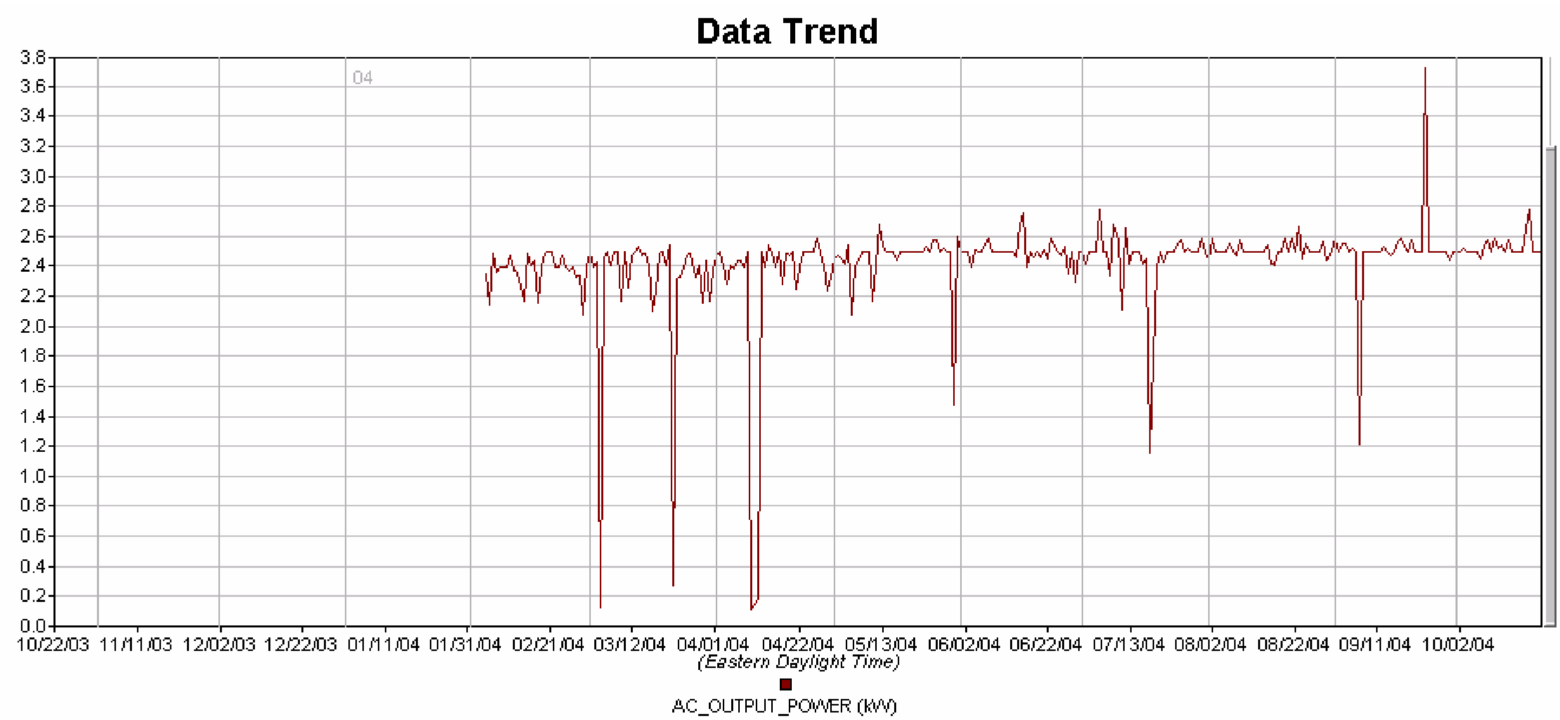
In summary, the lesson learned at this site will have positive implications for future PEM operations and customer services. As these experiences are transferred to future installations they will directly benefit the community of CERL projects and equally enhance the reliability of future Plug Power products. The project elevated the awareness of fuel cell technology at Ft. McPherson, educated the local community, and advanced the broader objectives of the fuel cell industry and product commercialization.

Appendix

1) Monthly Performance Data
2) Documentation of Installation Tasks and Acceptance Test
3) Daily Work Logs
4) FC Harmonics Test
5) Thermal Mapping
6) Explanation of Program Costs

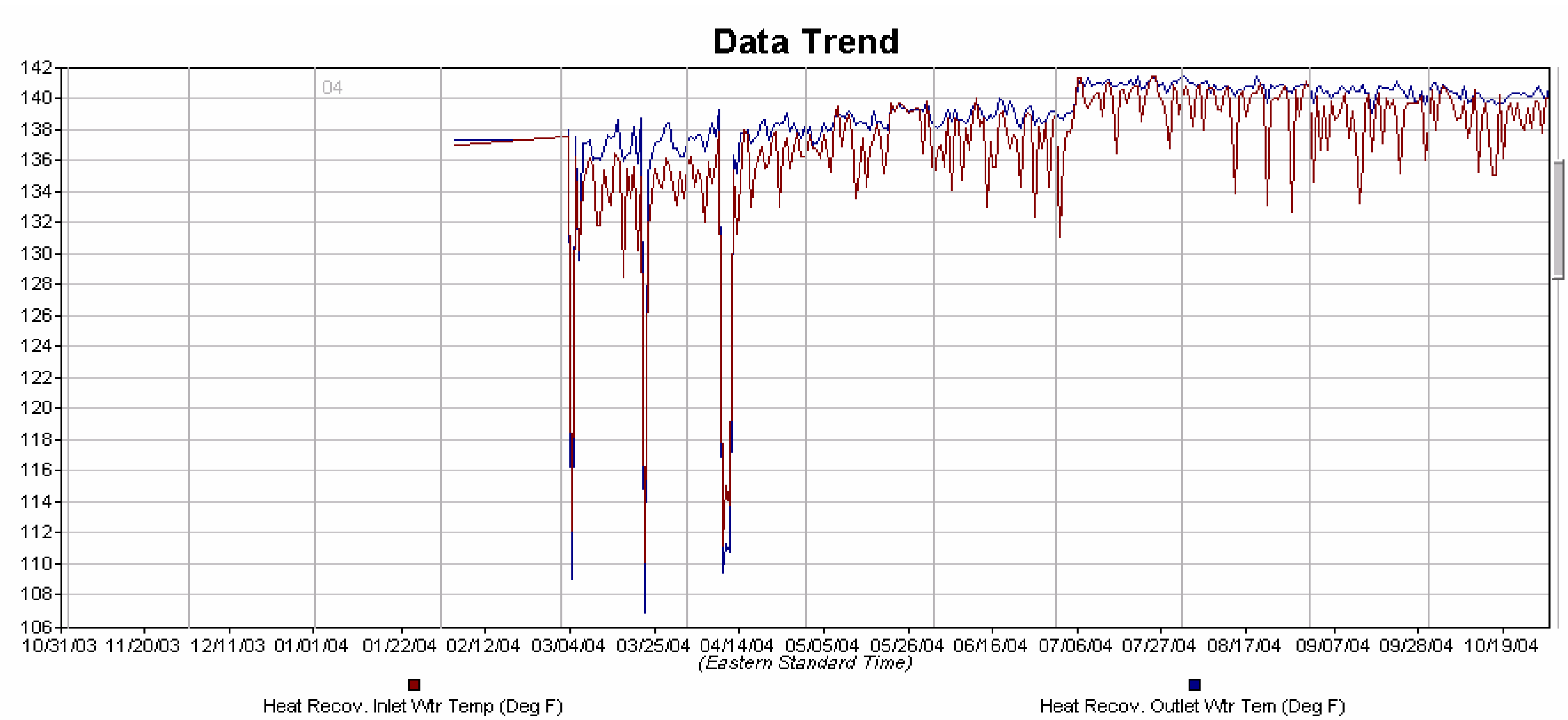
1) Monthly Performance Data

*AC POWER OUTPUT CHART, spanning a one-year period, from initial start (October 31, 2003).

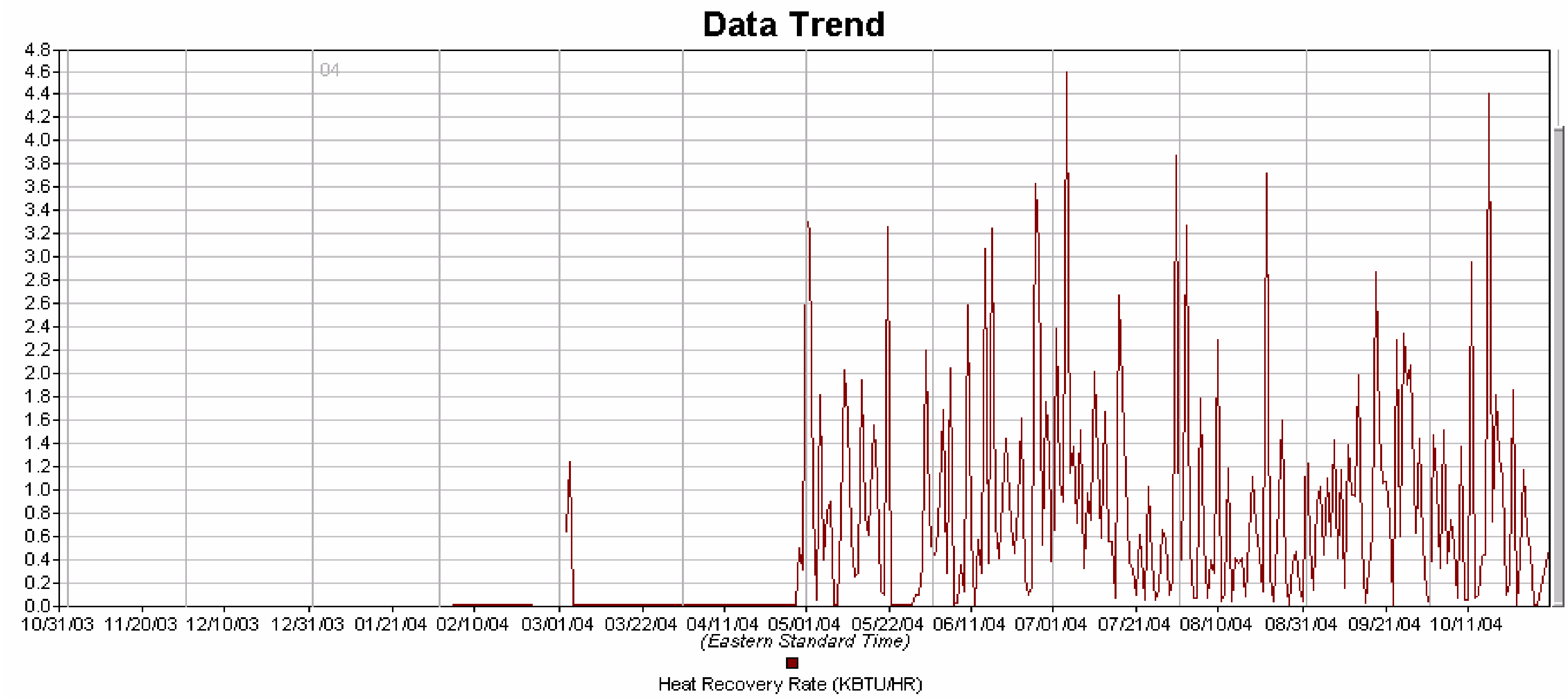


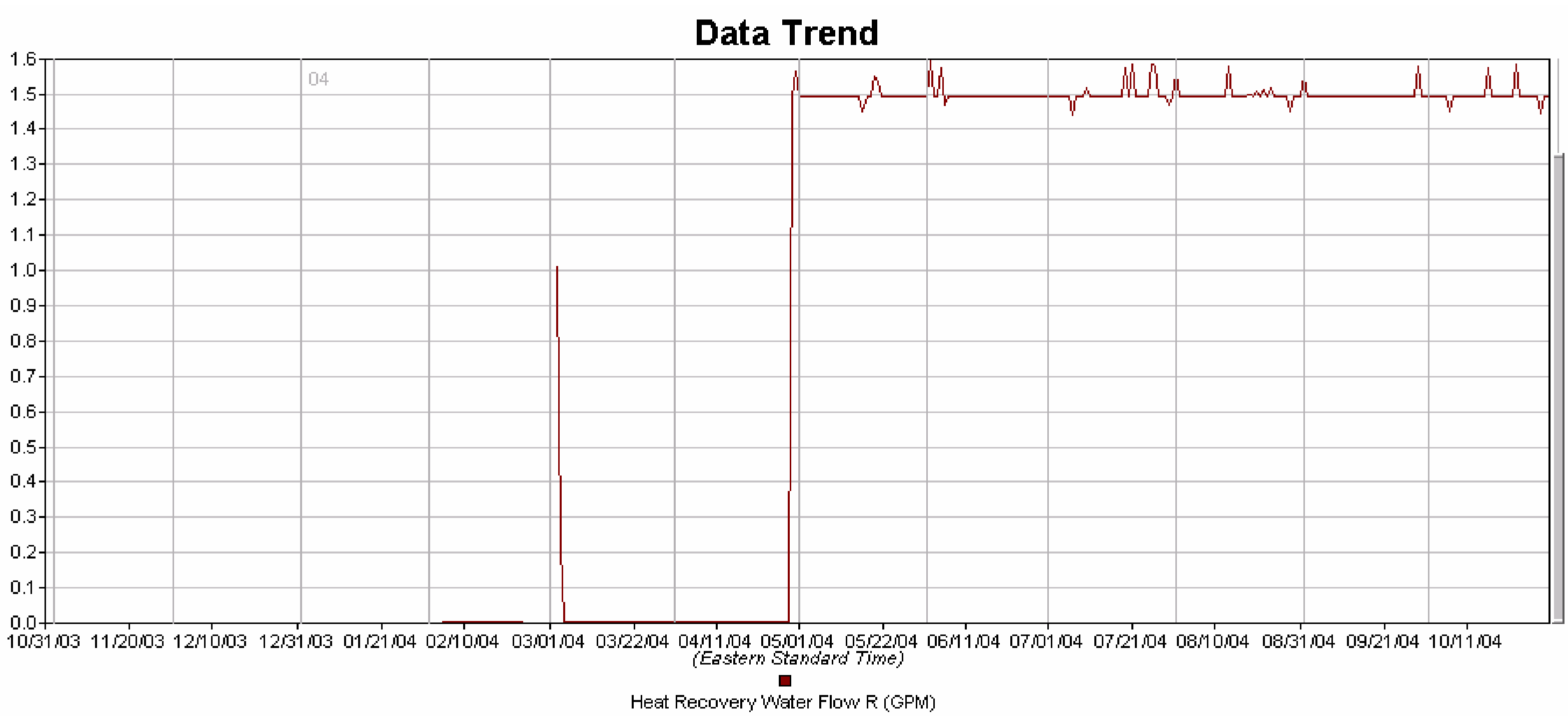
*See Work Logs in Appendix 2 for reference to periods of inoperability.

*HEAT RECOVERY INLET/OUTLET TEMPS, spanning a one-year period, from initial start (October 31, 2003).



*HEAT RECOVERY RATE, spanning a one-year period, from initial start (October 31, 2003).





*Monthly Fuel Cell Statistics:

Fort McPherson
Atlanta, Georgia

	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04
Run Time (Hours)	34	704	290	536	696	576	687	744
Time in Period (Hours)	34	720	744	744	696	744	720	744
Availability (%)	100.0%	98.0%	39.0%	72.0%	100.0%	77.0%	95.0%	100.0%
Energy Produced (kWe-hrs AC)	81.0	1,655.0	677.0	1,277.0	1,654.0	1,403.0	1,688.0	1,861.0
Output Setting (kW)	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Average Output (kW)	2.38	2.35	2.34	2.38	2.38	2.44	2.46	2.51
Capacity Factor (%)	47.7%	46.0%	18.2%	34.3%	47.5%	37.7%	46.9%	50.1%
Fuel Usage, LHV (BTUs)	1120000	23100000	9580000	5091	5084	5628	6861	7711
Fuel Usage (SCF)	1,108.0	22,811.0	9,471.0	17,172.0	17,148.0	18,983.0	23,143.0	26,009.0
Electrical Efficiency (%)	24.7%	24.5%	24.1%	25.1%	32.6%	25.0%	24.6%	24.2%
Thermal Heat Recovery (BTUs)								
Heat Recovery Rate (BTUs/hour)	0	0	0	0	0	0	0	0
Thermal Efficiency (%)	0%	0%	0%	0%	0%	0%	0%	0%
Overall Efficiency (%)	24.7%	24.5%	24.1%	25.1%	32.6%	25.0%	24.6%	24.2%
Number of Scheduled Outages	0	1	1	2	1	0	0	0
Scheduled Outage Hours	0	16	454	208	0.5	0	0	0
Number of Unscheduled Outages	0	0	0	0	0	1	1	0
Unscheduled Outage Hours	0	0	0	0	0	168	32.7	0

	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04
Run Time (Hours)	720	744	737	720	744
Time in Period (Hours)	720	744	744	720	744
Availability (%)	100%	100%	99%	100%	100%
Energy Produced (kWe-hrs AC)	1801.3	1855.3	1849.1	1817	1876.4
Output Setting (kW)	2.5	2.5	2.5	2.5	2.5
Average Output (kW)	2.50	2.49	2.51	2.52	2.52
Capacity Factor (%)	50.04%	49.87%	49.71%	50.46%	50.44%
Fuel Usage, LHV (BTUs)	7669.00	8084.00	7796.00	7407.00	8405.00
Fuel Usage (SCF)	25868.33	27268.17	26296.71	24984.58	28351.00
Electrical Efficiency (%)	23.50%	22.96%	23.73%	24.54%	22.34%
Thermal Heat Recovery (BTUs)	692830	725690	536720	795370	38460
Heat Recovery Rate (BTUs/hour)	962.2639	975.3898	728.2497	1104.681	51.69355
Thermal Efficiency (%)	2.65%	2.63%	2.02%	3.15%	0.13%
Overall Efficiency (%)	26.15%	25.59%	25.75%	27.69%	22.47%
Number of Scheduled Outages	0	0	1	0	0
Scheduled Outage Hours	0	0	7	0	0
Number of Unscheduled Outages	0	0	0	0	0
Unscheduled Outage Hours	0	0	0	0	0

2) Documentation of Installation Tasks and Acceptance Test

An 8-hour acceptance test was run on Oct 31, 2003 by the technician following completion of all the commissioning tasks listed in the Checklist attached below. It was the first successful start-up of the system. Please see Appendix 3 for documentation of the test done by the technician.

Installation/Acceptance Test Report

Site: Fort McPherson, Atlanta, GA

Installation Check List

TASK	Initials	DATE	TIME (hrs)
Batteries Installed	KW	9/23/03	2
Stack Installed	KW	8/19/03	3
Stack Coolant Installed	KW	9/23/03	1
Air Purged from Stack Coolant	KW	9/23/03	2
Radiator Coolant Installed	KW	9/23/03	3
Air Purged from Radiator Coolant	KW	9/23/03	1
J3 Cable Installed	KW	10/29/03	1
J3 Cable Wiring Tested	KW	10/29/03	0.5
Inverter Power Cable Installed	KW	9/24/03	0.5
Inverter Power Polarity Correct	KW	9/24/03	0.5
RS 232 /Modem Cable Installed	KW	10/29/03	0.5
DI Solenoid Cable Installed with Diode	KW	9/24/03	0.5
Natural Gas Pipe Installed	KW	9/24/03	8
DI Water / Heat Trace Installed	KW	9/24/03	4
Drain Tubing Installed	KW	9/23/03	1

Commissioning Check List and Acceptance Test

TASK	Initials	DATE	TIME (hrs)
Controls Powered Up and Communication OK	KW	10/30/03	4
SARC Name Correct	KW	10/30/03	1
Start-Up Initiated	KW	10/30/03	6
Coolant Leak Checked	KW	10/30/03	1
Flammable Gas Leak Checked	KW	10/30/03	1
Data Logging to Central Computer	KW	10/30/03	2
System Run for 8 Hours with No Failures	KW	10/31/03	8

3) Daily Work Logs
LOGANEnergy Field Technicians
(June 2003—September 2004)

LOGANEnergy Corp.

Monthly Site Report

Period **6/1/03**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
M. Harvell	6/3/03		Met with Luke Wyland to discuss fuel cell installation and look at some possible site locations.
	6/4/03		Kickoff meeting at McPherson with Nick Josefik. Inspected the general's home.

LOGANEnergy Corp.

Monthly Site Report

Period **8/1/03**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
	8/13/03	199	Preparation and talking with plumbing contractor.
	8/14/03		Bought concrete pads for fuel cell.
	8/18/03		Drove to McPherson with Vince Enriquez, bought gravel and worked on the pad.
	8/19/03		Rented a forklift. Set the fuel cell, after finishing pad. Installed the stack.
	8/20/03		Met with 2 contractors at the site to get bids.

LOGANEnergy Corp.

Monthly Site Report

Period	**9/1/03**		
Site	Ft. McPherson		
Engineer	**Date**	**PP S/N**	**Summary/Milestones**
Mike Harvell	09/15/03	199	Gathered info and parts.
	09/16/03		Bought supplies.
	09/17/03		Drove to base. Met with Luke, who contacted utility markers to come out and mark underground lines. Shopped for supplies.
	09/18/03		Worked with contractors on electrical and plumbing.
	09/19/03		Worked with contractors. Drove home.
	09/22/03		Drove to base.
	09/23/03		Electricians finished up. I soldered control wires at Heliodyne, spliced control wires under the house, powered up fuel cell and started procedures. Had some issues with SARC not responding.
	09/24/03		Loaded newest software on SARC, filled glycol and therminol systems. Buried 75 ft. of RO waste line. Ordered CAT5 with shield. Drove home.

LOGANEnergy Corp.

Monthly Site Report

Period **10/1/03**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Mike Harvell	10/29/03	199	Drove to McPherson. Met K. Williams. We pulled cable from fuel cell to storage unit and hung CE box.
	10/30/03		I worked on starting the fuel cell while Keith worked on the CE box connections. Drove home that night.
K Williams	10/29/03		drove to Atlanta to connect Connected Energy's box
K Williams	10/30/03		returned to site and finished connections and drove home

LOGANEnergy Corp.

Monthly Site Report

Period **11/1/03**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Harvell	11/24/03	199	Drove to Atlanta.
	11/25/03		Checked phone line polarity which was good. Replaced SARC and loaded battery file. Phone problem was in base phone system. Worked on Connected Energy box and installed 2 light bulbs in storage unit to keep DI system from freezing.
PEM Rpt	11/26/03		Intermittent data transfer. Data transfers stopped on 11/12, then received a successful upload on 11/15 but none since. Check phone line for correct polarity and voltage. Tried to connect to system via phone line and keep getting busy signal.

LOGANEnergy Corp.

Monthly Site Report

Period **12/1/03**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
M Harvell	12/15/03	199	Drove to Atlanta.
	12/16/03		Troubleshooting CL issue. Found a battery that had a loose connection and melted area around it. Tried again to get CE box wired correctly, but there is still an issue.
			Restarted unit, but peak shaving (and shutdown) followed the next morning.

LOGANEnergy Corp.

Monthly Site Report

Period **1/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
K Williams	1/23/04	199	Internet cable installed.
Mike Harvell	1/27/04	199	Keith and I went out there to work on the Connected Energy box, to no avail. Found NG meter to not be working.

LOGANEnergy Corp.

Monthly Site Report

Period **2/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Mike Harvell	2/4/04		1 bad RDT on the water heater return line. Replaced 3 water filters. NG meter problems are due to the pulse counters mounted on them. A clicking sound in the meter was noted (when the counter causes its failure).
Mike Harvell	2/11/04		Went by to try something Connected Energy wanted me to try in order to get the readouts on the Web to change, but it did not help. They will be contacting us with a fix.
	2/19/04		System Status: Running Recommended maintenance: Load SARC v1.28
	2/20/04		System Status: Running – requires maintenance

			Recommended maintenance: Inverter is cycling between charge control mode 3 and 5. Check inverter calibrations and tightness of all connections. Recommendations from engineering were emailed to Mike on Friday. Also, Load SARC v1.28.
	2/26/04	199	Fuel cell was cycling between modes 3 and 5 on the inverter. Tested the inverter voltages and amps, relayed them to Plug, shut the fuel cell down, input new commands to the inverter to recalibrate it, then restarted.

LOGANEnergy Corp.

Monthly Site Report

Period **3/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
M Harvell	3/1/04		System Status: Running – requires service
K Williams			Recommended maintenance: Inverter is cycling between charge control mode 3 and 5. Setpoint changes made by Mike and Garnett did not correct the problem. Inverter needs replacement. Inverter shipped to Mike Harvell, should be delivered today.
	3/2/04		System Status: Running Incident Description: Inverter cycling between charge control mode 3 and 5. Incident Resolution: (3/2) I called the system this morning and it is running well and not switching to charge control 5. I will continue to monitor performance. Hold off on replacing the inverter for now. Recommended maintenance: Load SARC v1.28
	3/3/04	199	At McPherson with Melissa and Keith. Worked on CE box and got most of it working, but have some issues remaining with the flow meters. Got the gas meter to start working without having to change it out. Loaded new software into the SARC. Had some shutdown issues late in the day related to the CE box.
K Williams	3/4/04	199	Again with Melissa and Keith working mainly on the CE box. Fixed the RTD problem but the flow meters would not work at all. Had to restart the fuel cell as it shut down again the night before because of a false signal it was receiving from the CE box, but we did resolve that issue. Dropped them off at the airport and drove home.
	3/5/04		System Status: Running
	3/11/04		System Status: Running Incident Description: No data transfer via modem, cannot communicate to the system via modem. This has been the case since SARC v1.28 was loaded. May require a site visit to verify setpoints and possibly power down and restart the unit. (3/11) I spoke to Mike Harvell this morning, the unit needs to be powered down and rebooted.

	3/11/04	199	Met Jeff Worley and took him to see a fuel cell and to chat about the job. Fixed a modem callout issue and some incorrect data logging info that had the communications tied up in knots (couldn't call in or out).
	3/11/04		System Status: Running Incident Description: No data transfer via modem, cannot communicate to the system via modem. This has been the case since SARC v1.28 was loaded. May require a site visit to verify setpoints and possibly power down and restart the unit. (3/11) I spoke to Mike Harvell this morning, the unit needs to be powered down and rebooted.
	3/12/04		System Status: Running Incident Description: Mike Harvell was at the site yesterday. Established comms to his PC, re-configured data logging (call out number was incorrect), performed a modem test (passed) and I was able to establish comm remotely. Call in data was received this morning; system is running well.
M Harvell	3/21/04	199	Fuel cell shut down at 7:30am. Drove to site, changed water filters and restarted.
			COMSYS detected the following alarm: ALARM: Fuel Cell B199 Shutdown ALARM TIME: Mar 22 2004 7:19AM EST EQUIPMENT: Plug Power Fuel Cell SITE: Ft. McPherson
	3/22/04		System Status: **Shutdown** Incident Description: SHUTDOWN, HUMIDIFIER_TOP_HIGH_SD Incident Resolution: Check DI panel operation and restart.

LOGANEnergy Corp.

Monthly Site Report

Period **4/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
			Sent: Saturday, April 10, 2004 4:50 AM Subject: System SU01B000000199 shut down
	4/12/04		System Status: **Shut-down - 4/10/2004 4:51:00 AM** Incident Description: SHUTDOWN, HUMIDIFER_TOP_HIGH_SD, Error Code: (248)(0) Recommended maintenance: Inspect DI water system and filter assembly.
	4/12/04	199	Fuel cell shut down on Hum Top High. Changed RO filter and restarted.

			Drove to Atlanta and got McPherson back up and running Monday. Just filter problems. The issue there is not the water, but the pressure. It gets low, so the RO filter doesn't pass adequate water volume. Drove back home Monday night. Went to Sumter Tuesday to change out the e-wheel and restart. I had checked on NCAT that morning via modem and noticed a "stack coolant low alert". Didn't want to chance a shutdown with just 10 days to go, so I drove to Greensboro to remedy that and check on the filters there, returning home today. Sent: Saturday, April 10, 2004 4:50 AM Subject: System SU01B000000199 shut down
Worley	4/23/04		Travel to McPherson to work on flow meter problems. Flow meters not pulsing Connected Energy card. Unable to resolve issue this trip.
Worley	4/29/04		Troubleshoot problems with Comcast Modem. Modem lost "activation". After several phone calls to Comcast, Terayon, and Connected Energy, it was discovered that the modem had lost its activation with the Comcast service provider. Note: If you have problems with Comcast call tech support and ask for Pamela. She appears to know more than all of their other technicians combined.

LOGANEnergy Corp.

Monthly Site Report

Period **6/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Worley	6/15/04	199	Tues. - Repaired damaged flowmeter in secondary CHP loop. Also verified that all temperature sensors are wired correctly. While at the site I noticed that the hotwater heater temps are higher than the temps in the CHP loop. I turned hot water heater thermostat down slightly to address this issue. Also, gas meter is damaged and no longer sending pulses to Connected Energy.
Worley	6/15/04	199	Wednesday - Travel to Mchpherson to replace dial/pulse assembly on gas meter. Meter now operational and ready for visit by P. Armstrong of Pacific Northwest Labs.

			Also, swapped RTD inputs on secondary CHP loop to get enerview site working correctly.

LOGANEnergy Corp.

Monthly Site Report

Period **7/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Worley	7/6/04	199	Tuesday - Met Peter Armstrong of Pacific Northwest Laboratories at site to complete site performance analysis. Took harmonics readings, BTU readings, and exhaust gas analysis. Peter wil prepare a technical report evaluating fuel cell performance. Also noticed that RTD's installed in CHP loops do not have the same installation depths in all locations. In particular, the RTD's on the primary loop are further away from the flow stream than those on the secondary CHP loop. This could be the reason for the low temperatures seen on the enerview website. As an experiment, I insulated the RTD's on the primary loop to see if the temperature difference would be affected.
	7/7/04		System Status: Running Incident Description: Did not call in to Plug Power this morning, Connected Energy web site indicates the system is running
S Logan	7/17/04		According to the CE online data, the system updated last at 18.57 Friday evening, but the unit appears to be running normally today at 1300 because the thermal loop temps appear to be normal for 2.5 kW, even though the power output indicates only .6 kW. Do you suppose we are having conflicts between the SARC and the CE system like we are seeing at the Coast Guard site? They appear to have very similar based on screen displays. We should investigate Ft Mac first of the week just to be sure! Has anyone been thinking about how to correct the problem? These sites are visible to the public and we need to make sure the data is accurate.
K Williams			If it is the same sort of problem, we need to look at something other than the new style SARC. It was thought that the newest SARC had hardware conflicts that kept it from communicating completely with the Connected
K Williams	7/19/04		Brian, I wanted you to be aware that the Connected Energy at Ft.Mac is back working and doesn't appear to have been a problem with the Plug Power end of the system. Although it stopped updating data Friday when it came back on Sunday it caught up by unloading its buffer. The only issue we still have is with the "new" SARC at the Coast Guard.

Worley	7/29/04		I then plan to hit McPherson Thursday or Friday to take care of the thermal mapping.

LOGANEnergy Corp.

Monthly Site Report

Period **8/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
	8/13/04	199	System Status: Running – requires maintenance Maintenance: kW hours = 14648 as of 12:00 AM on 8/12; system is overdue for 12000 kWh maintenance. Please call Tech Support to order the maintenance kit.
	8/18/04		System Status: Running – requires maintenance Maintenance: kW hours = 14648 as of 12:00 AM on 8/12; system is overdue for 12000 kWh maintenance. Maintenance kit has been shipped to Jeff Worley.
Worley	8/19/04		It is about 1:15pm on Thursday. I am at Ft Mac finishing up the 12000 kwh PM. It looks like the stack gained a couple of volts. This should help when I return to do thermal mapping.
Worley	8/27/04		COMSYS detected the following alarm: ALARM: Fuel Cell B199 Shutdown ALARM TIME: Aug 27 2004 10:06AM EDT EQUIPMENT: Plug Power Fuel Cell SITE: Ft. McPherson Stopped by McPherson to do a little work on the DI system. I shut it down around 10:00am. It should be running by lunchtime.
Worley	8/19/04	199	Thursday - Drove to McPherson. Completed 12000kwh PM. Drove Home

LOGANEnergy Corp.

Monthly Site Report

Period **9/1/04**

Site Ft. McPherson

Engineer	Date	PP S/N	Summary/Milestones
Worley	9/23/04	199	Thursday - Stopped at McPherson on the way back from Cherry Point. Completed thermal mapping and harmonics.

LOGANEnergy Corp.

Monthly Site Report

Period November-04

Site Fort McPherson 199

Engineer	Date		Summary/Milestones
	11/11/2004		1100149277,11/11/2004 12:01:17 AM,Running (51)ALERT, H2_STOICH_HIGH, Error Code: (520)(0) 1100163465,11/11/2004 3:57:45 AM,Running (51)SHUTDOWN, INVERTER_NOT_EXPORTING_AC, Error Code: (570)(0) 1100163465,11/11/2004 3:57:45 AM,SD Ref Cool (104)EVENT, SHUTDOWN_EVENT, Error Code: (1001)(0)
Worley	11/22/2004	192	I spent the day decommissioning Fort McPherson. Most of the work inside of the house is complete. I have a meter base, flowmeters, RTD's and a Heliodyne to take over to GA tech. Removed heliodyne unit and returned domestic hot water piping to its original configuration. Removed sub-meter and base. Removed all mounting brackets, screws, etc. from walls.

LOGANEnergy Corp.

Monthly Site Report

Period December-04

Site Fort McPherson 199

Engineer	Date	Summary/Milestones
	12/21/2004	Removed all conduit and CHP piping from house. Disconnected sub-meter from main gass line. Installed pipe plug in gas line tap. Removed Connected Energy box and cable modem.

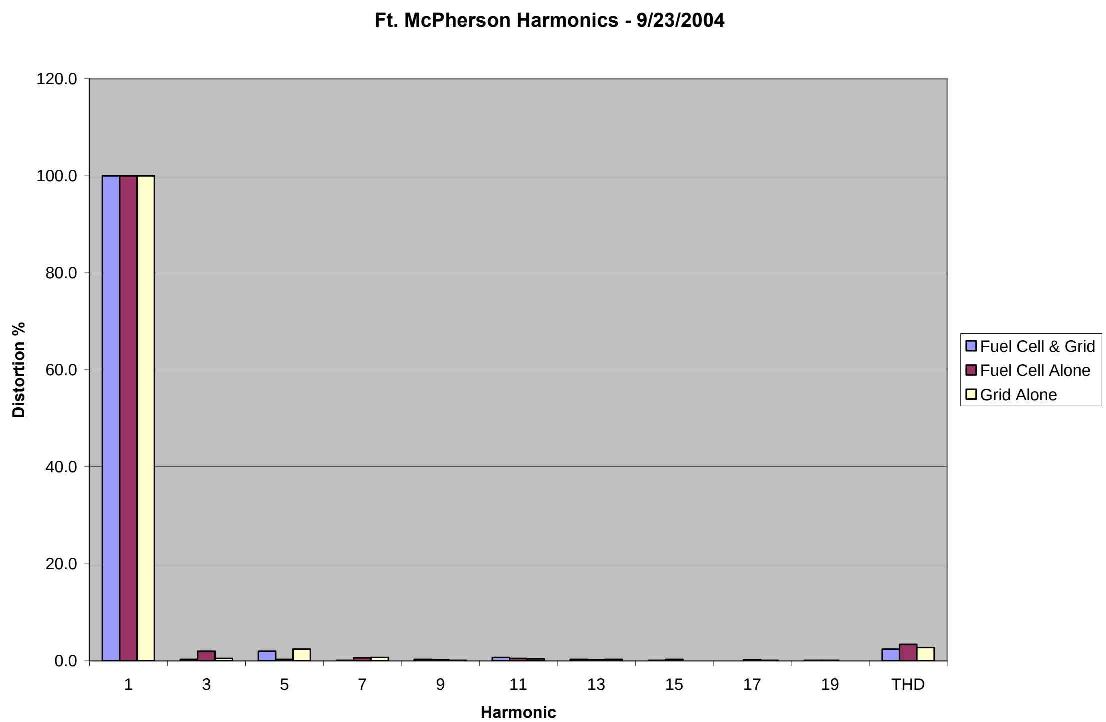
4. Harmonics Test

The data box and resultant graph below depict the test parameters and the resultant distortion of the 1st through 19th harmonics of GenSys S/N 199 captured during a test conducted on September 23, 2004 with an Amp Probe HA-2000 Harmonics Analyzer.

Fort McPherson Harmonics Data

Date 9/23/2004 Time 1:45pm Tech: Worley

Fuel cell	4.0 kW		4.0 kW		Off	
Grid Present	Yes		No		Yes	
Harmonic	Volts	Percent	Volts	Percent	Volts	Percent
1	122.5	100.0	119.1	100.0	121.4	100.0
3	0.390	0.3	2.392	2.0	0.725	0.5
5	2.484	2.0	0.390	0.3	3.019	2.4
7	0.227	0.1	0.780	0.6	0.936	0.7
9	0.417	0.3	0.350	0.2	0.237	0.1
11	0.884	0.7	0.688	0.5	0.555	0.4
13	0.465	0.3	0.287	0.2	0.458	0.3
15	0.174	0.1	0.459	0.3	0.092	0.0
17	0.047	0.0	0.252	0.2	0.173	0.1
19	0.163	0.1	0.237	0.1	0.117	0.0
THD		2.4		3.4		2.7



The test results indicate that Plug Power GenSys S/N 199 inverter was performing at a level consistent with the manufacturer's specifications.

5. Thermal Mapping

On September 23, 2004 LOGAN field personnel also mapped the thermal efficiency of the waste heat integration of the fuel cell with the host facility. The chart and graphs depicting those results are attached below

Clock Hour	Minute	Second	Temp from Water Heater: Temp Out	Temp In	ΔT	Tank Temp °F	Elapsed Time Hours	Calculated: Low °F	High °F	ΔT °F	Check Calcs ΔT °F	Btu/Hour	Gallons Water Heated Per Hour	Gallons Water Heated In Tank	% Tank Heated
0	0	0	88.2	91.8	3.6	81.4	0	88.2	91.8	3.6	3.6	7,284			
0	10	0	89.2	96.1	6.9	83.3	0.1667	89.2	96.1	6.9	6.9	13,961	21.76	3.63	9.1%
0	20	0	96.8	101.5	4.7	87.1	0.1667	96.8	101.5	4.7	4.7	9,510	24.04	7.63	19.1%
0	30	0	102.2	108	5.8	89.7	0.1667	102.2	108.0	5.8	5.8	11,735	21.76	11.26	28.2%
0	40	0	108.7	113.4	4.7	92.5	0.1667	108.7	113.4	4.7	4.7	9,510	21.76	14.89	37.2%
0	50	0	114.1	117.7	3.6	94.8	0.1667	114.1	117.7	3.6	3.6	7,284	17.20	17.75	44.4%
1	0	0	117.3	120.9	3.6	95.7	0.1667	117.3	120.9	3.6	3.6	7,284	14.92	20.24	50.6%
1	10	0	120.6	123.1	2.5	97	0.1667	120.6	123.1	2.5	2.5	5,058	12.64	22.35	55.9%
1	20	0	123.9	126.3	2.4	99	0.1667	123.9	126.3	2.4	2.4	4,856	10.16	24.04	60.1%
1	30	0	126	128.5	2.5	1017	0.1667	126.0	128.5	2.5	2.5	5,058	10.16	25.73	64.3%
1	40	0	128.1	130.6	2.5	1033	0.1667	128.1	130.6	2.5	2.5	5,058	10.36	27.46	68.7%
1	50	0	130.3	132.8	2.5	1031	0.1667	130.3	132.8	2.5	2.5	5,058	10.36	29.19	73.0%
2	0	0	132.4	133.9	1.5	1053	0.1667	132.4	133.9	1.5	1.5	3,035	8.29	30.57	76.4%
2	10	0	134.6	136	1.4	1065	0.1667	134.6	136.0	1.4	1.4	2,833	6.01	31.57	78.9%
2	20	0	135.7	137.1	1.4	1076	0.1667	135.7	137.1	1.4	1.4	2,833	5.80	32.54	81.3%
2	30	0	136.8	138.2	1.4	1082	0.1667	136.8	138.2	1.4	1.4	2,833	5.80	33.51	83.8%

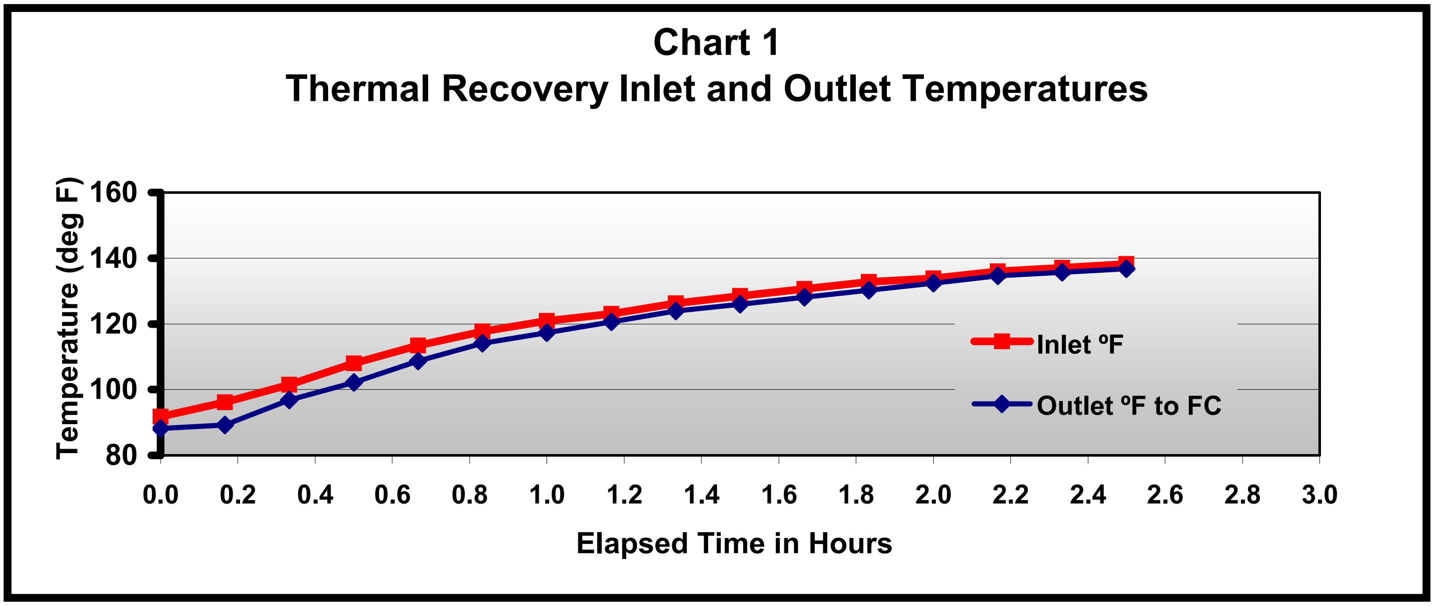


Chart 1
Thermal Recovery Inlet and Outlet Temperatures
Temperature (deg F)
160
140
120
100
80
Inlet ºF
Outlet ºF to FC
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
Elapsed Time in Hours

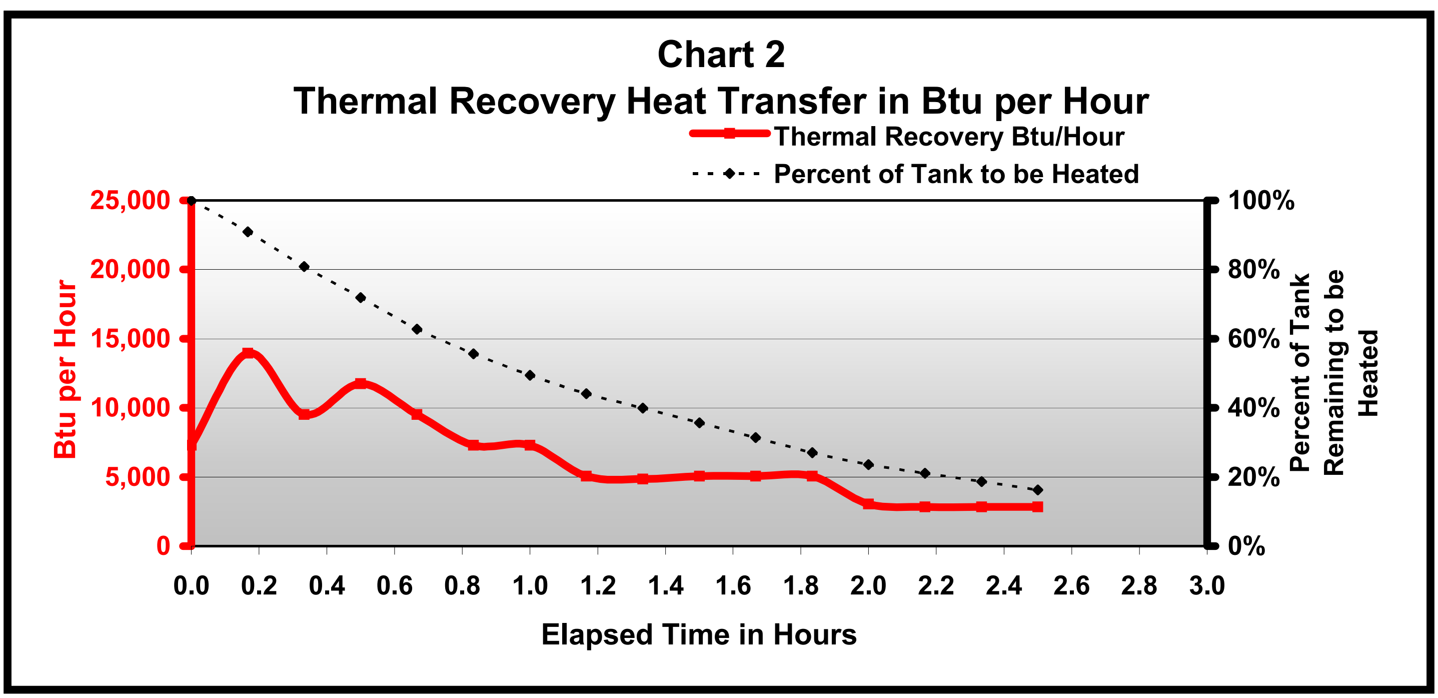


Chart 2
Thermal Recovery Heat Transfer in Btu per Hour
Thermal Recovery Btu/Hour
Percent of Tank to be Heated
Btu per Hour
25,000
20,000
15,000
10,000
5,000
0
100%
80%
60%
40%
20%
0%
Percent of Tank Remaining to be Heated
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
Elapsed Time in Hours

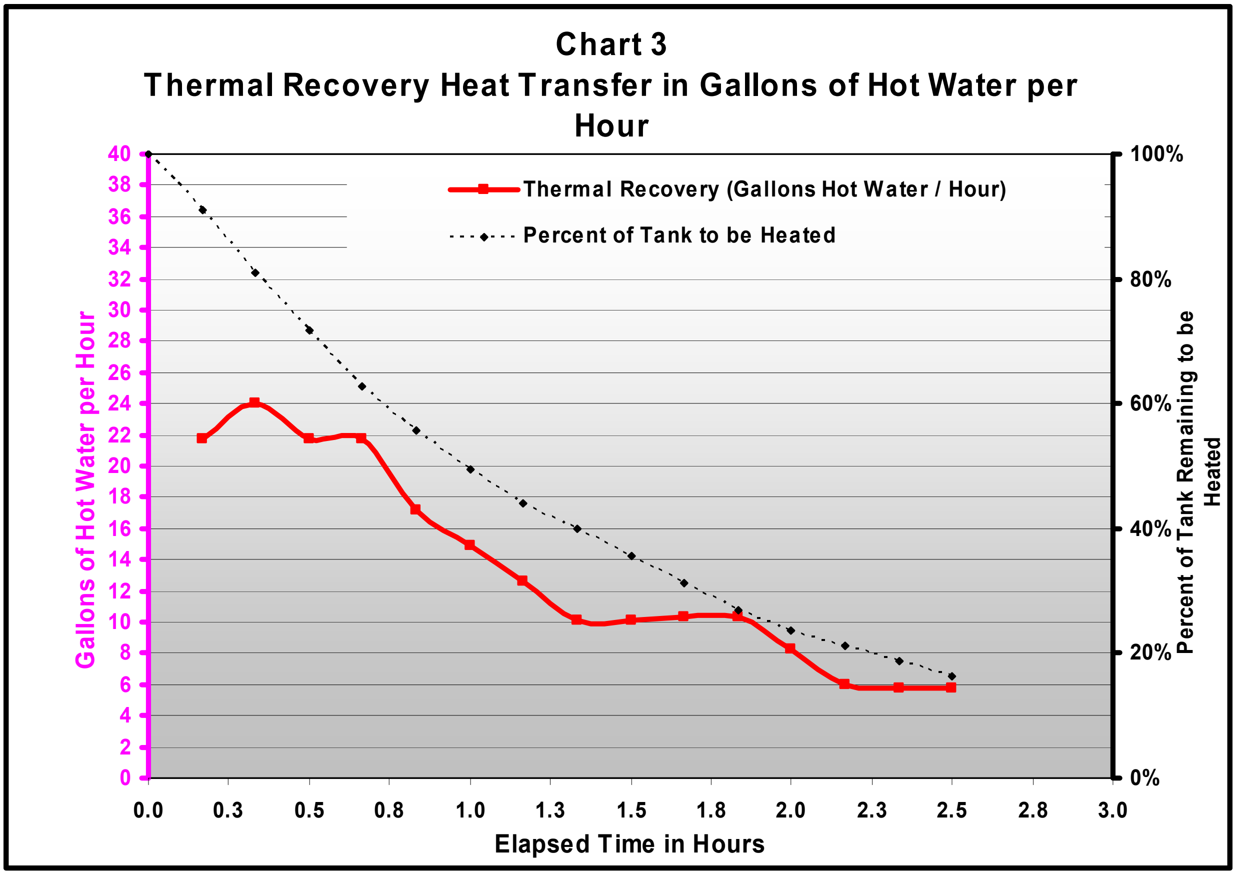


Chart 3
Thermal Recovery Heat Transfer in Gallons of Hot Water per Hour
Thermal Recovery (Gallons Hot Water / Hour)
Percent of Tank to be Heated
Gallons of Hot Water per Hour
Percent of Tank Remaining to be Heated
Elapsed Time in Hours
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100%
80%
60%
40%
20%
0%
0.0
0.3
0.5
0.8
1.0
1.3
1.5
1.8
2.0
2.3
2.5
2.8
3.0

6. Explanation of Program Costs

Explanation of Calculations:

Program costs may be broken down into three broad categories as illustrated in the chart above. They are **First Cost**, **Annual Technical Services**, and **Annual Operating Expenses**. The first category labeled **First Cost** has been further delineated into two columns labeled **Estimated** and **Actual**. The estimated and actual costs draw a distinction between those construction/installation costs originally **Budgeted** for the project as opposed to the **Actual** costs to complete the project. In this case, the **Actual** project **First Cost** was $599 less that the amount originally **Budgeted**. While the electrical installation portion of the project cost less than originally supposed, the increase in the mechanical and thermal recovery line item more than offset the savings in the electrical cost category. Since the installation encountered fewer technical issues than originally considered, and since the initial start-up went smoother than planned, the Technical Supervision/Start-up line item cost less than the budget amount

The category labeled **Annual Technical Services** breaks out several categories of costs and expenses that were required to support the project for the test period. The **Variance** in this category amounted to $4,802 dollars less than originally budgeted. The primary reason for this **Variance** was due to the unit requiring fewer hours to support than originally **Budgeted** for service and maintenance costs. However, report writing was not originally **Budgeted** as a project line item and appears as a large **Variance** to the original budget.

The last category labeled **Annual Operating Expenses** breaks out the fuel cell operating costs for the test period.
The **Budgeted** cost of natural gas consumed during the project was calculated on operating the fuel cell system at 2.5 kW thereby consuming 0.033 Mcf per hour natural gas. That cost per hour is $0.19 Mcf per hour *x* the cost of natural gas to McPherson per Mcf at $5.80. The cost per year at $1501.59 is the cost per hour at $0.19 *x* 8760 hours per year *x* 0.9. The 0.9 is for 90% availability. This cost may also be expressed as $0.0762 per kWh produced by the fuel cell.
The **Actual** cost of natural gas for the program came to $1604 or a **Variance** of $103 dollars. This was due to the increase in operating hours and to a slightly higher than projected hourly fuel cell consumption rate to .0351Mcf/h from .0328Mcf/h.
Natural gas fuel cell systems set at 2.5 kW will consume 1.6 gallons of water per hour through the DI panel. The total volume of water consumed at 14,016 gallons per year is 1.6 gph *x* 8760 hours per year. The cost per year at $18.36 is 14,016 gph *x* cost of water to McPherson at $1.31 per 1000 gallons.
The **Budgeted** Total Annual Operating Cost, $1520 is the *sum of* the cost per year for the natural gas and the cost for the water consumption. The **Actual** costs follow as a result of data collected during the project.

Economic Summary:

The Forecast Annual kWh **Budgeted** at 19,710 kWh is the product of 2.5 kW set point for the fuel cell system *x* 8760 hours per year *x* 0.9. The 0.9 is for 90% availability. The actual project kWh has been entered in the column labeled **Actual** with the forecast **Variance** in the column to the right.
The Annual Cost of Operating the Power Plant at $0.077 per kWH was **Budgeted** by calculating the Total Annual Operating Cost at $1520 *divided by* the forecast annual kWh at 19,710 kWh. The **Actual** cost was calculated using the real program results
The Credit for Annual Thermal Recovery of $0.018/kWH was **Budgeted** by calculating 7800 BTU per hour thermal recovery at 2.5 kW *divided* by 3414BTU/kWh *multiplied* .20 recovery factor, *multiplied* by $0.039/kWh. As a credit to the cost summary, the value is expressed as a

negative number. The **Actual** value of thermal recovery was calculated using the Btu data captured during the project and has been expressed as a credit to the project. The **Variance** is expressed in $/KWh.

The **Budgeted** Project Net Operating Cost is the *sum* of the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery. The **Actual** Operating Cost is similarly calculated.

The Displaced Utility Cost is the kWh cost of electricity paid by Fort McPherson. The original **Budgeted** and the **Actual** results are contrasted in the two labeled columns.

Energy Savings (cost) equals the Displaced Utility Cost *minus* the Project Net Operating Cost.

Annual Energy Savings (cost) equals the Energy Savings *x* the Forecast Annual kWh.